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# Winds of fortune? Understanding the geographic, sociodemographic, and temporal distribution of benefit mechanisms from land-based wind projects in the United States

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ABSTRACT

Despite decades of research on factors shaping local responses to wind development, there is relatively little known about benefit mechanisms (e.g., agreements, funds, donations) used by developers in the U.S. land-based wind sector. To address this gap, we collected benefit mechanism data across all current utility-scale land-based wind projects installed between 1982 and 2024 (n = 1047), finding that just under one-third of projects had a benefit mechanism attached to them. We find the use of benefit mechanisms has become more common over time, is associated with larger projects, and varies by region. In terms of host community characteristics, the use of benefit mechanisms is associated with characteristics like higher education level, higher percent white, higher percent Republican, higher decision-making capacity, lower unemployment rate, and higher poverty rate. Building on a theoretical framework of purposes, we discuss what these findings could suggest about the motivations driving developers' use of these mechanisms, such as increasing local acceptance of a wind project or supporting distributive fairness. This first-of-its-kind study builds a comprehensive understanding of how benefit mechanisms have been used in the U.S. wind industry throughout its history, which can inform future approaches to benefit-sharing across sectors.

## 1. Introduction

### 1.1. Benefit mechanisms in the U.S. land-based wind context

Wind energy is an abundant energy source making an increasingly large contribution to the U.S. electricity sector, but the deployment of wind energy hinges in part on the willingness of communities to host wind projects. A large body of research has explored community responses to and relationships with wind energy [1–5], considering factors that are both procedural (e.g., decision-making processes, community engagement) [6–9] and distributive (i.e., distribution of benefits like tax revenues and burdens like visual impacts) [10–13], among others. In some countries and sectors, much of this research has focused on mechanisms such as community benefit agreements, which developers may use to provide additional benefits to the communities hosting their projects [14–19]. Given that community benefit agreements are uncommon in the U.S. land-based wind sector, a broader, more flexible term is useful in this context; we use the term "benefit mechanism," which describes any voluntary benefit given to a community in relation to a wind project, coming in various forms such as an agreement, fund, donation, or nonfinancial benefit.

The use of benefit mechanisms in land-based wind development has historically been more limited in the United States than in countries like the United Kingdom and Ireland [20], and as such, there has been relatively little research on the topic in this context. There are many ways that wind energy development delivers economic benefits to communities hosting or living near projects—some that are required or standard in most industrial development, like property and sales taxes, and others that are more specific to wind energy, like landowner lease payments [21]. As a result, land-based wind projects in the United States create myriad positive economic impacts in host communities, such as economic diversification and increased school funding [22–24]. In this context, additional benefits delivered through a benefit mechanism might not be seen as necessary from the community perspective or financially feasible from the developer perspective.

Benefit mechanisms can be used to achieve certain aims for

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developers and communities alike, giving them various purposes within the development and operation of wind energy projects [25–27]. The use of a benefit mechanism could help developers increase local support for a project, form long-term positive relationships with the community, fairly distribute benefits among communities, and compensate for impacts. Depending on the purpose for which a benefit mechanism was used in a given context, one might expect to see a different approach to design and implementation of the mechanism; for example, which groups receive benefits, the size of the financial investment, and the timing of benefit distribution are key considerations that might vary depending on the motivations of those involved [28–30]. Understanding connections between the ways that benefit mechanisms are implemented and the purpose for their use is one of the key objectives of this study.

### 1.2. Approach and motivation

Based on field notes from previous unstructured interviews with more than 30 community members, local leaders, federal government representatives, developers, researchers, and consultants/lawyers,[1] we identified a lack of data and knowledge concerning the role benefit mechanisms have played in the U.S. land-based wind sector and varying opinions about the purposes they might have. Moreover, while our interviews and literature review pointed to certain trends in the use of benefit mechanisms—like an increase in use over time—the lack of data and large-scale research on this topic in the United States made it impossible to conclusively identify these trends on a national level.

In this study, we build a baseline understanding of how benefit mechanisms have been used in the deployment of land-based wind energy in the United States by collecting and analyzing a comprehensive dataset of benefit mechanism information. Though building this dataset had its own intrinsic benefits—such as democratizing access to this information for wind host communities—we also aimed to identify trends related to project characteristics (e.g., size, year) and community characteristics (e.g., demographics, economic activities).

In Section 2, we propose a theoretical framework for understanding the purposes for using benefit mechanisms based on the factors we found to be the most prevalent and salient for wind energy in the U.S. context. In Section 3, we discuss our methodology for data collection and analysis, and in Section 4, we present results related to project characteristics, community characteristics, and geographic variation. We also present two regression models that use the aforementioned characteristics to explain the outcome of a project having or not having a benefit mechanism. In Section 5, we discuss the practical significance of and potential explanations for our findings, and we use our findings to discuss which purpose for benefit mechanisms the data might best fit, as an exploratory approach to identify whether ascertaining purpose from actual use could be possible. We were motivated by the following research questions:

- How do U.S. wind projects with benefit mechanisms differ from those without them, in terms of project size, age, and region and in terms of the economic status, racial demographics, and decision-making capacity of project host communities?
- Is it possible to explain the existence of a benefit mechanism based on project and community characteristics?
- What does the actual use of wind energy benefit mechanisms suggest about the purpose for their use?

[1] We conducted 30–60-min interviews from March to August 2023. Additionally, we hosted a peer exchange workshop with about 20 local, Tribal, and regional leaders and consultants in August 2023; findings from this workshop also helped to shape our approach to this study.

## 2. Establishing a framework for the purposes for benefit mechanisms

There is no singular purpose for using a benefit mechanism, as the international literature on this topic reveals. Purposes may include increasing local support, spreading positive economic impacts, recognizing communities as hosts for infrastructure, accounting for impact and/or compensating for losses, supporting community engagement, being good neighbors, and reducing project risk [25–27]. These “overlapping motives” [26] are not necessarily at odds with each other, as the “fluidity of meaning allows the concept [of community benefits] to hold together a range of interests” [31]. Determining purpose is not merely a theoretical exercise, as it has substantive implications for what approach is taken in each case; for example, benefits might be concentrated with the local government if obtaining an approval was the purpose or given to impacted groups if the purpose was compensating for losses. This “constructive ambiguity” in purpose allows benefit mechanisms to be adapted to a variety of circumstances and to be used for a variety of ends [31].

When the purpose for providing benefits is not made explicit by the actor providing them, the important question of intent is left open for communities and other stakeholders to form their own interpretations [32,33]. Different stakeholders are likely to view the motive or purpose differently, and views can “range between the extremes of the altruistic where developer philanthropy meets community interests to the cynical and highly skeptical [sic] of [community benefit agreements] as developer bribes to effectively buy a planning consent” [34]. Leaving the question of intent open-ended may then seem risky, but if “specifying the aim of a compensation measure may increase or decrease the effectiveness of compensation” [32], then there could be a strategic advantage for developers to keep their motives private [33].

While it is valuable to examine the purposes described by researchers in other countries and/or other sectors, we found it necessary to create a framework of purposes specific to the U.S. land-based wind context. Missing from much of the existing literature is distributive fairness, an increasingly influential consideration in the deployment of energy projects in the United States. Additionally, there has generally been little consideration of the role of benefit mechanisms across the project’s entire lifetime, rather than merely the oft-studied development stage [35]. With this framework, our intention is not to examine explicitly stated motives or rationalizations; rather, we aim to examine the hypothetical utility benefit mechanisms have in different areas, which we conceptualize as four purposes in Table 1.

These purposes are not specific to the developer’s perspective; they could also describe a community’s motivation for engaging in benefit negotiations or a policymaker’s motivation for creating a benefit

**Table 1**
A framework of purposes for using benefit mechanisms in the context of U.S. land-based wind energy.

| Purpose | Description |
|---|---|
| Social acceptance | Increasing community acceptance of and/or support for a wind project during the development stage, making it more likely to receive necessary permits and approvals and ultimately be constructed. |
| Long-term relationship-building | Fostering long-term positive relationships between a developer and community and ensuring ongoing support for the project’s presence throughout the operational life of a wind project. |
| Distributive fairness | Fairly distributing the benefits from a wind project among different groups or communities—particularly those who are burdened and/or vulnerable—supported by a fair process for making decisions about the benefits. |
| Compensation for impacts | Compensating for negative impacts (both actual and potential) from a wind project that could not be avoided (e.g., visual impacts, revenue losses in sectors like tourism and agriculture, environmental impacts). |

mechanism requirement. But given the historical lack of such requirements in the United States, it is the developer who holds the purse strings and much of the power in deciding whether benefit mechanisms are used [14]; as such, we focus primarily on interrogating the underpinnings of developers' actions in this area.

In the following sections, we establish the theoretical and practical foundations for these purposes, with greater attention paid to the social acceptance and distributive fairness purposes that factor into this study's analysis. The other two purposes, long-term relationship-building and compensation for impacts, would be difficult to address with our approach to data collection and analysis, as we believe they would require more dedicated attention to the timing, form, and content of individual benefit mechanisms. We identify avenues for future research focused on these two purposes in our discussion section.

### 2.1. Benefit mechanisms for social acceptance

A critical purpose for developers using benefit mechanisms is increasing community support for or acceptance of a proposed wind project. Historically in the United States, the function of community benefit agreements across sectors has been that the signatory representing the community "exchanges public and political support of a proposed development project for a slate of economic benefits" [36], so there is a built-in expectation that communities are giving something in return for what they receive. Opposition provides communities with leverage, which can help to initiate benefit mechanism processes and buoy the community's position in negotiations. In keeping with this, though, increasing social acceptance is "inherently limited" as a rationale for benefits because "it implies that without opposition there is no reason to provide compensation" [37].

The connection between benefits and assuaged opposition is most straightforward when the community (or the party representing the community, like a local government) has siting or permitting authority over the proposed project, as "negotiations around the exchange of property rights are moments when power is enacted, resisted, and created" [27]. Gaining acceptance and support from a broad swath of the community—not just acquiescence from the local government—is a different challenge, one that is perhaps less transactional than exchanging benefits for a project permit. In terms of community-wide social acceptance, a benefit mechanism may make community members feel they are sharing more fairly in the project's benefits [37] or participating more meaningfully in its decision-making [38], both of which can engender support. In this way, a benefit mechanism could be considered "a mechanism to enhance community participation and foster collaboration between developers and local stakeholders" [38]. Benefits may also lessen or at least acknowledge the concerns community members had about the project [31,39] through targeted support for certain issues.

Despite these sound explanations for how benefit mechanisms should work to support social acceptance, this relationship is contested. Benefit mechanisms have been found to increase local acceptance under specific conditions [32,40–42] but also to have no significant impact or even to create a boomerang effect leading to increased opposition [29,40,42,43], especially when communities perceive the offer of benefits as a bribe to buy local support [40,43–45]. Even when the offer of benefits is not ill-received, disapproval and conflicts related to key decisions about the mechanism can also produce opposition [32,46,47]. If ensuring local support is the purpose of benefit mechanisms, then developers likely weigh these considerations when deciding whether to use them, as "the underlying economic logic is that decisions that might increase local community benefits … are not worthwhile to developers unless this improves their profitability" [48]. If developers can assuage opposition and gain support in less costly and more guaranteed ways, then using benefit mechanisms may be hard to justify.

### 2.2. Benefit mechanisms for long-term relationship-building

Paradigms that consider more long-term relationship-building and approval dynamics are favored by some over the social acceptance paradigm, which looks more narrowly at the point of acceptance of proposed project development. Social license to operate is a useful concept oriented around ongoing acceptance of and support for a project or a company's operations; components of this include social legitimacy, credibility, and trust [49]. Benefit mechanisms could support the ongoing social license to operate because they can be negotiated and given at any point in the project's life [32]. If unexpected negative impacts have arisen or the community has not seen the positive impacts it expected to see, conceivably the community and developer could jointly use a benefit mechanism to rectify these issues [32]. In this way, benefit mechanisms could be used continuously throughout project operations to help ensure the social license is upheld and the community's approval is ongoing.

Continuous approval is particularly useful if "it also enhances the likelihood of future projects being successful" [50] or if a developer seeks approvals to repower or otherwise extend the life of an existing project [35,51]. On the other hand, disapproval of how a benefit mechanism has been carried out over time could harm community perceptions of the project at key future decision points like approval of a repower [51]. Also, if community approval (or at least the absence of disapproval) is required in exchange for benefits, the benefit mechanism "may inhibit communities from voicing concerns in the future, consequently diminishing future decision-making power" [52].

### 2.3. Benefit mechanisms for distributive fairness

An emerging narrative in the United States is that the purpose of benefit mechanisms is to fairly distribute the benefits of an energy project among different groups or stakeholders. The concept of "spreading the positive" could apply here in the general sense of making sure regional- or national-level benefits from wind projects fairly percolate to the local level where the project is sited [25]. More specifically, though, some communities or groups of people have historically not received a fair share of benefits from the U.S. energy system [53], and it has been posited that benefit mechanisms can help to redress past imbalances [54,55]. Benefit mechanisms can be viewed through the lens of multiple tenets of fairness—not only distributive fairness, which focuses on fair distribution of benefits and burdens from the energy system [56], but also procedural fairness, in the sense that decision-making processes for benefit mechanisms may be more or less fair [44,47].

If benefit mechanisms are to be an effective tool for distributive fairness, there must be some consideration of the unique needs and history of each community. However, understanding a community's precise needs and addressing them with a benefit mechanism takes additional time and resources for developers and communities alike [57] and may be considered a lower priority than obtaining local approvals and permits. But compared to the social acceptance paradigm, in which benefit mechanisms are a means to an end, "seeing community benefits as a corollary of justice makes them a social obligation" [54]. If sufficiently motivating, this could change the rationale for developers to provide benefits and potentially make benefit mechanisms more commonly and universally used—and it could shift power in negotiations to "favour the beneficiaries" [58].

However, benefit mechanisms cannot be uncritically assumed to support distributive fairness. Whether they fulfill this role depends in part on decision-making processes and how the mechanism is structured and implemented, hinging significantly on the power dynamics that are involved [14,29,58–60]. For example, a community-led process that results in a benefit package with provisions directed at uplifting certain vulnerable community members is one possible process and outcome. Another is that wealthier communities and those with more resources and capacity to engage may present greater opposition to projects and greater power in benefit negotiations, resulting in developers providing them with more benefits than communities with less power [44,52,54,61–63]. There is nothing inherently unfair about benefit mechanisms and the impacts they have, but they are also not inherently fair.

### 2.4. Benefit mechanisms as compensation for impacts

Through the siting and permitting processes involved in wind development, there are often mitigation measures that a developer must take to address impacts from their project; though easy to conflate, it is an important distinction that benefit mechanisms differ from financial compensation required by a regulatory process [31]. Rather than directly compensating for a specific loss or impact, benefit mechanisms can help developers to more generally acknowledge and make up for negative impacts by providing the community with something positive [39,61]. In some cases, benefits might be conceptually linked to impacts, such as a donation to a local nature center in a host community concerned about a project's impacts on wildlife. But this voluntary type of impact compensation achieved through some benefit mechanisms is more a matter of perception than it is literal one-to-one compensation; compensation can "take on a partly symbolic function, reflecting society's feelings that some reparation should be forthcoming, while recognizing that compensation fully equivalent to what was lost may not be possible" [31].

Compensation as a term could be associated with connotations that a developer may seek to avoid [27,57], as it is an implicit acknowledgement that an energy project inflicts a harm or burden that the developer is liable for addressing [37]. This idea that benefit mechanisms are used to "fix" either tangible problems or the "psychic costs of living near a public harm" [63] could be perceived positively by those who feel they are bearing the brunt of such problems or costs, but it carries some risk of lending increased legitimacy and attention to negative aspects or perceptions of a project [33].

## 3. Methodology

### 3.1. Dependent variable: benefit mechanisms

Our dependent variable was a binary outcome: the presence or absence of a benefit mechanism. As stated previously, we define benefit mechanisms broadly as any voluntary benefit given to a community in relation to a wind project, which includes agreements, funds, payments to local governments outside of an agreement, donations, and nonfinancial benefits. Because some states have implemented contingent policies encouraging or requiring the use of benefit mechanisms (e.g., Maine's law requiring community benefit packages for wind development on certain types of land), "voluntary" as a term may have some caveats in this context; many of these laws are relatively new, though, compared to our sample of projects. Generally, in most locations in the United States, benefit mechanisms are used voluntarily.

Rather than examining a sample of wind projects, we were motivated to take a census of all utility-scale land-based wind projects currently constructed in the United States. We downloaded the metadata from the U.S. Wind Turbine Database [64] in November 2023, setting a parameter that the sample would include only projects that were fully or partially built at that time. The projects in our sample were constructed between 1982 and 2024.[2] Though we could not verify that all of these projects are active or operational, the infrastructure is still in place; we excluded projects that had been fully decommissioned. As the focus of this study is utility-scale projects, we removed any projects with fewer than 10 turbines from the sample. Additionally, we removed and/or combined some duplicate projects (e.g., repowered projects that were listed twice). The final sample consisted of 1047 projects, which can be found in Appendix A. We retrieved project details (name, year, location, and number of turbines) from the Wind Turbine Database, but some supplementary information (e.g., developer, nameplate generating capacity) and any corrections of details were gathered from developer or state government websites (e.g., public utility commission data).

The first stage of finding benefit mechanism information for each project was a series of online searches, using the following search terms: "*project name* + *developer name* + community benefit," "*project name* + *developer name* + community benefit agreement," "*project name* + *developer name* + community benefit fund," and "*project name* + *developer name* + donation." In some cases, "*county name*" was added to searches for additional specificity. Additional searches were conducted as needed for each project; for example, searching for "*project name* + *developer name* + scholarship" if there was some evidence that a scholarship fund might have been established. Documents reviewed through these searches included news articles, press releases, fact sheets, webpages, social media posts, government meeting and budget documents, and project documents filed with local and state governments (e.g., economic impact studies).

The second stage consisted of emailing the developers and host communities involved in each project to verify the information collected and identify any benefit mechanisms that were not documented or that may have been missed by our online searches. We sent one email per developer and per community involved in the project; for example, for a project that changed hands between two developers and was located in two counties, we would have sent four emails. We did not send follow-up emails unless we received a response. In some cases, we received no response or received a response stating that the information was not available or could not be shared; in the United States, where benefit mechanisms are largely unregulated, this information is considered proprietary by many developers. If information received through either stage of data collection was inconclusive, we engaged in additional searches and in some cases contacted additional parties.

Our goal in this data collection was solely to assess the presence or absence of a benefit mechanism for each wind project. Though we engage with concepts of purpose in this study, we did not seek to make observations related to articulations of purpose. For example, when reviewing a developer's press release, we would note if a benefit mechanism was described, but we would not analyze the language used within the press release or attend to any statements of motive put forth by the developer. Details related to characteristics of the benefit mechanisms themselves, such as structure and monetary value, were collected for use in our future research.

### 3.2. Independent variables: project and community characteristics

With our first research question, we sought to understand how U.S. wind projects with benefit mechanisms differ from those without benefit mechanisms in terms of project age and size. Based on our background knowledge stemming from interviews and existing literature, we believed it was likely that projects with benefit mechanisms would be newer and larger. We hypothesized:

**H1.** : On average, projects with benefit mechanisms are newer (operationalized as *year of operation*) than projects without benefit mechanisms.

**H2.** : On average, projects with benefit mechanisms are larger (operationalized as *number of turbines* and *nameplate generating capacity in megawatts* [MW]) than projects without benefit mechanisms.

Another aspect of our first research question was understanding how projects with and without benefit mechanisms differ in terms of three community characteristics: racial demographics, economic status, and

[2] Two projects were assigned 2024 as a year of operation because they were under construction as of November 2023.

decision-making capacity. We viewed these as key indicators of communities' level of comparative advantage or disadvantage, as well as being key components of what gives communities power in energy decision-making.

"Community" is a contextually defined and at times contested term, but in the context of this study, we define the community as the county or counties where wind turbines are sited. Community characteristics were selected with attention to the key variables involved in social acceptance and distributive fairness because a relationship between these variables and the provision of benefits could yield valuable insights about the aims that benefits serve. Data for the 34 selected variables were collected from publicly available datasets; see Appendix A for the list of variables and sources. Data were collected at the county level, with 479 unique counties represented; presence of an abandoned mine was the only variable at the census district level, but we considered a county to have this characteristic if at least one census district in the county satisfied the requirement. For wind projects in multiple counties, we averaged all variables except for population size, which was aggregated. Community characteristics data were primarily from the years 2018–2022.

To operationalize economic status, racial demographics, and decision-making capacity, we selected three representative metrics to test as hypotheses; a larger number of community characteristics are included in our logistic regression models introduced in Section 4.4. We hypothesized:

**H3**. : Projects with benefit mechanisms and without benefit mechanisms differ significantly in terms of their host community's *median household income.*

**H4**. : Projects with benefit mechanisms and without benefit mechanisms differ significantly in terms of the proportion of host community members who identify as *white alone.*[3]

**H5**. : Projects with benefit mechanisms and without benefit mechanisms differ significantly in terms of their host community's *rural capacity index.*[4]

### 3.3. Data analysis

We computed descriptive statistics and *t*-tests to analyze community- and project-related differences between projects with benefit mechanisms and projects without; we also computed chi-square tests to analyze geographic differences. We then developed logistic regression models that included the project and community characteristics variables as independent variables and benefit mechanism/no benefit mechanism as the binary dependent variable. Given our large sample size of projects (n = 1047), we were able to include all 34 project and community characteristics variables in an initial regression model. We then removed variables to produce two more specific regression models.

## 4. Results

In this section, we present results related to the project, community, and geographic characteristics of projects with and without benefit mechanisms. We also present and interpret the results of our two logistic regression models, which use the presence of a benefit mechanism as the dependent variable. Given the cross-sectional design of our study, it should be noted that we can only identify associations between these variables and not causal relationships.

### 4.1. Project characteristics

We found that 31.8 % of projects in the sample had benefit mechanisms (n = 333) and 68.2 % of projects did not (n = 714). Projects with benefit mechanisms were significantly newer ($p < 0.001$) and larger (in terms of generating capacity [$p < 0.001$] and number of turbines [$p < 0.01$]) than those without, supporting our first and second hypotheses. Table 2 shows results from descriptive statistics and *t*-tests for each characteristic.

To view year-over-year changes in the usage of benefit mechanisms, we graphed the percentage of projects with a benefit mechanism installed each year from 1999 to 2023 (Fig. 1). We excluded projects from the years 1982–1998 because only a very small number of projects were installed each year during that period, creating outliers; 2024 was excluded because it similarly had a very small number of projects due to our cut-off date for data collection. After some inconsistency from 1999 to 2004, the percentage of projects with benefit mechanisms tends to grow somewhat steadily from 27.7 % in 2005 to 42.3 % in 2023.

For generating capacity, we grouped the projects into similarly sized buckets and calculated the percentage of projects with a benefit mechanism within each bucket (Fig. 2). On the low end, 12.9 % of the smallest projects (0.7–29.9 MW; n = 124) had a benefit mechanism, compared to 44.6 % of the largest projects (264–1050 MW; n = 112) on the high end. Interestingly, the highest-capacity projects tended to dip back down to a lower rate of usage of benefit mechanisms. Only 36.6 % of the 30 projects larger than 350 MW had a benefit mechanism. Of the six projects between 683.2 and 1050 MW, only one used a benefit mechanism. Fig. 3 shows the 30 largest projects in terms of generating capacity, again grouped into similarly sized buckets.

Lastly, we treated number of turbines the same way as generating capacity, by grouping projects into buckets of similar size and graphing the percentage of projects with a benefit mechanism (Fig. 4). 16.2 % of projects with 10–20 turbines (n = 136) had a benefit mechanism, compared to 44.8 % of projects with 95–119 turbines (n = 125). Again, there is a dip at the high end, with only 32.8 % of projects with 120–460 turbines (n = 131) having a benefit mechanism. This tracks with the finding that the highest-capacity projects had a lower rate of benefit mechanism usage, with the additional factor that very old projects (which tend to have a large number of small turbines) tended to not have benefit mechanisms.

### 4.2. Community characteristics

The three community characteristics we focused our hypotheses on were median household income, percent white, and rural capacity index, as we viewed these to be key indicators of economic status, racial demographics, and decision-making capacity. We found that projects with benefit mechanisms and projects without benefit mechanisms had a significant difference in terms of their host communities' median household income ($p < 0.05$) and percent white alone ($p < 0.001$), on average, which supports our third and fourth hypotheses. We did not find a significant difference in rural capacity index between the two groups, so there is a lack of support for our fifth hypothesis. Based on our finding that percent white alone was significant, we conducted *t*-tests for each of the other racial demographics, finding that percent Black ($p < 0.05$), percent Asian ($p < 0.01$), percent Hispanic ($p < 0.01$), and percent two or more races ($p < 0.05$) were also significant. Table 3 shows results from descriptive statistics and two-tailed t-tests for each characteristic.

We ultimately calculated *t*-tests and descriptive statistics for all 34 community characteristics variables to ensure we were aware of any variables that might be significant for our modeling efforts. In Table 4, we present results for those variables found to be significant through our *t*-tests, as well as variables we later found to be significant in our models

[3] U.S. Census data offer multiple racial demographic data options; "percent white alone" represents the percentage of people who identify as only white, without any other racial or ethnic identities (e.g., Hispanic or Latino, multiple races).

[4] A composite index from Headwaters Economics measuring the "level of staffing, resources, and expertise a community needs to successfully apply for funding, manage complex grant processes, and plan and maintain infrastructure improvements" [65].

**Table 2**
Descriptive statistics and two-sample one-tailed *t*-tests for project characteristics.

| Characteristic | With benefit mechanism | | | Without benefit mechanism | | | *Sig.* |
|---|---|---|---|---|---|---|---|
| | Mean | Median | SD | Mean | Median | SD | |
| Year of operation | 2014.49 | 2015 | 5.65 | 2012.04 | 2012 | 6.89 | 0.000*** |
| Generating capacity (MW) | 167.02 | 150 | 105.5 | 132.58 | 102.7 | 111.6 | 0.000*** |
| Number of turbines | 74.15 | 67 | 44.3 | 66.65 | 55 | 56.1 | 0.0098** |

*p*-Value: ***$p < 0.001$, **$p < 0.01$, *$p < 0.05$, +$p < 0.1$.

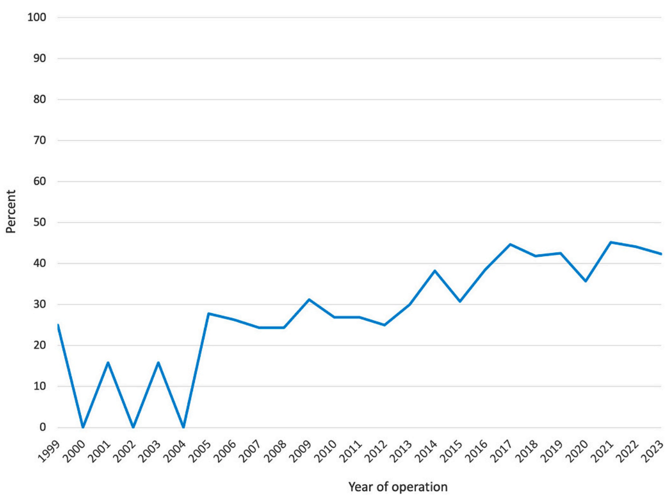


**Fig. 1.** Proportion of wind projects that have benefit mechanisms, based on year project began operating.

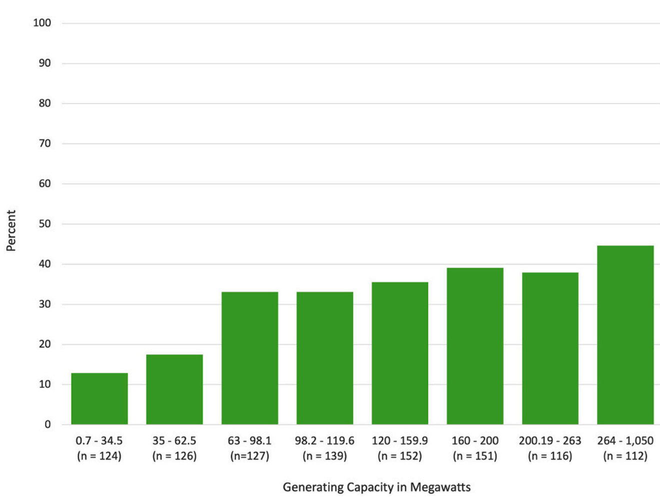


**Fig. 2.** Proportion of wind projects that have benefit mechanisms, in ranges of generating capacity in megawatts.

(even if they were not significant in our *t*-tests). We find projects with benefit mechanisms tend to have host communities with lower home values, lower population density, lower unemployment rate, lower market value for agricultural products, lower population, lower social vulnerability, higher energy burden, lower linguistic isolation rate, lower rate of Internet access, and lower natural amenities score.

### *4.3. Geographic differences*

Another aspect of our first research question was understanding how projects with and without benefit mechanisms differed based on their region, and we found significant regional variation. We ran a chi-square

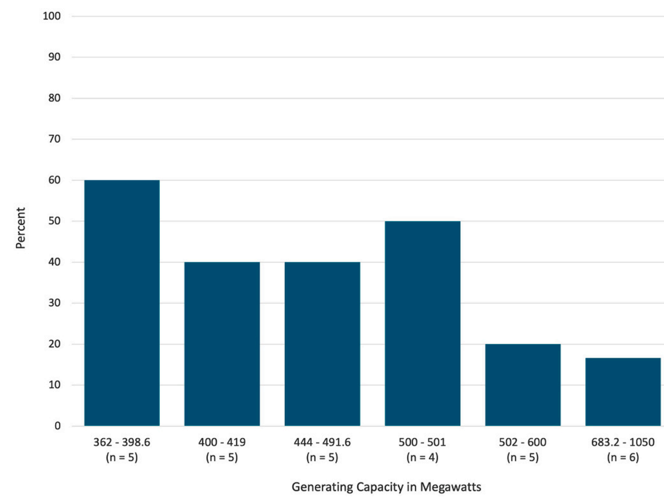


**Fig. 3.** Proportion of wind projects that have benefit mechanisms, in ranges of generating capacity in megawatts, for the 30 largest wind projects.

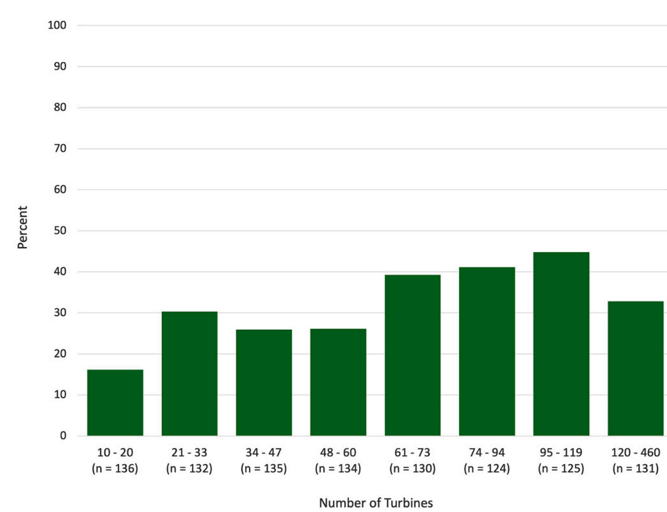


**Fig. 4.** Proportion of wind projects that have benefit mechanisms, in ranges based on number of turbines.

test that found that state has a dependent relationship with benefit mechanisms ($p < 0.001$). The same was true for region ($p < 0.001$); we used regions defined by the U.S. Bureau of Economic Analysis and added Puerto Rico to the Southeast region. We found that the percentage of projects in each region that have benefit mechanisms attached to them range widely (Fig. 5) from 12.67 % of projects in the Far West region (Alaska, Hawaii, Pacific Coast; n = 150) to 78.26 % of projects in New England (n = 23).

**Table 3**
Descriptive statistics and two-sample two-tailed *t*-tests for median income, racial demographics, and rural capacity index.

| Characteristic | With benefit mechanism | | | Without benefit mechanism | | | *Sig.* |
|---|---|---|---|---|---|---|---|
| | Mean | Median | SD | Mean | Median | SD | |
| Median household income | 63,079 | 62,547 | 10,871 | 65,012 | 63,883 | 13,337 | 0.013* |
| Percent white alone | 83.44 | 88.7 | 13.79 | 79.54 | 85.5 | 15.75 | 0.000*** |
| Percent Black | 3.03 | 2.1 | 3.14 | 3.54 | 2.3 | 3.53 | 0.018* |
| Percent American Indian/Alaska Native | 3.35 | 1.5 | 6.90 | 2.92 | 2 | 5.08 | 0.311 |
| Percent Asian | 1.64 | 0.9 | 4.44 | 2.66 | 1.1 | 5.57 | 0.002** |
| Percent Hispanic or Latino | 17.13 | 7.2 | 23.17 | 21.76 | 11.07 | 22.73 | 0.003** |
| Percent Pacific Islander/Native Hawaiian | 0.36 | 0.1 | 2.04 | 0.49 | 0.1 | 2.33 | 0.373 |
| Two or more races | 7.69 | 4.55 | 7.41 | 8.98 | 7.1 | 6.76 | 0.007** |
| Rural capacity index | 66.64 | 68.17 | 11.22 | 66.61 | 68.33 | 12.05 | 0.970 |

*p*-Value: ***$p < 0.001$, **$p < 0.01$, *$p < 0.05$, +$p < 0.1$.

**Table 4**
Descriptive statistics and two-sample two-tailed *t*-tests for additional community characteristics.

| Characteristic | With benefit mechanism | | | Without benefit mechanism | | | *Sig.* |
|---|---|---|---|---|---|---|---|
| | Mean | Median | SD | Mean | Median | SD | |
| Median value of owner-occupied housing units | 165,495 | 143,000 | 93,434 | 187,463 | 146,200 | 127,233 | 0.002** |
| Population density | 19.16 | 8.1 | 47.01 | 30.44 | 7.5 | 90.34 | 0.008** |
| Unemployment rate | 3.47 | 3.2 | 1.47 | 3.74 | 3.5 | 1.51 | 0.007** |
| Poverty rate | 13.72 | 12.9 | 4.48 | 13.73 | 12.6 | 4.47 | 0.974 |
| Market value of agricultural products sold (average per farm) | 329,132 | 248,220 | 429,098 | 441,376 | 247,839 | 629,687 | 0.0007*** |
| Population | 82,784 | 23,266 | 281,454 | 172,023 | 22,798 | 450,568 | 0.0001*** |
| Social vulnerability | 42.48 | 38.21 | 28.98 | 48.53 | 45.55 | 29.90 | 0.002** |
| Energy burden | 3.55 | 3.5 | 1.18 | 3.39 | 3.5 | 1.11 | 0.041* |
| Linguistic isolation rate | 5.53 | 2.4 | 8.78 | 6.71 | 3.1 | 8.34 | 0.041* |
| Percent with broadband access | 82.39 | 83.7 | 7.79 | 83.54 | 84.1 | 5.55 | 0.016* |
| Percent employed in agriculture, forestry, fishing, hunting, mining | 10.30 | 8.6 | 8.13 | 12.50 | 9.4 | 31.65 | 0.08+ |
| Percent Republican | 69.47 | 72 | 13.93 | 68.25 | 70 | 14.40 | 0.191 |
| Percent 25 years or older with a bachelor's degree or higher | 22.35 | 21.5 | 6.10 | 21.88 | 20.9 | 6.93 | 0.271 |
| Natural amenities scale | −0.448 | −0.52 | 2.43 | 0.475 | 0.43 | 2.83 | 0.000*** |

*p*-Value: ***$p < 0.001$, **$p < 0.01$, *$p < 0.05$, +$p < 0.1$.

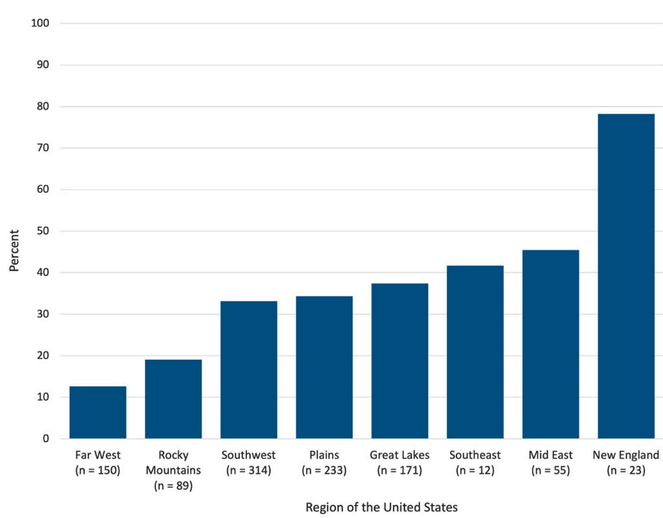


**Fig. 5.** Proportion of wind projects in each U.S. region that have benefit mechanisms.

### 4.4. Logistic regression models

With our second research question, we sought to understand whether we could use community and project characteristics to explain the presence or absence of a benefit mechanism. To do so, we used an iterative model selection process to create two logistic regression models. Initially, we included as independent variables a broad suite of metrics related to demographics, socioeconomic status, education and decision-making capacity, agriculture, economic activities and industries, natural amenities, and political affiliation and voting behaviors. Given our interest in understanding the purpose for benefit mechanisms, these variables were selected based on (a) prior studies studying the characteristics associated with opposition to wind projects [3,66] and (b) data tools used to assess community advantages and disadvantages in the energy/environment context [67,68].

Our goal in using regression models was to identify how the relationships and trends we have identified thus far might be affected when multiple independent variables are interacting with each other, as well as to identify new relationships not present in our earlier analysis. Through testing and comparing initial iterations of the models, we progressively removed some variables to reduce multicollinearity and improve model fit. To assess multicollinearity, we computed variance inflation factor (VIF) values continuously as we created the models and initially removed any variables with a VIF $> 5$; we ultimately retained one variable in our second model that had a VIF slightly above 5 (median home value; VIF $= 5.4$) because including the variable improved model fit. We also used a correlation matrix to ensure none of our variables were excessively correlated with each other. Ultimately, this process of paring down the initial large number of variables helped to produce models that were better-forming and more parsimonious, with less correlation between variables.

Our first model, called the **National Model** because it includes no region variables, shows that several variables have significant relationships with the use of benefit mechanisms (Table 5). Year of operation ($p < 0.001$), number of turbines ($p < 0.01$), percentage of adults 25 years or older with a bachelor's degree or higher ($p < 0.05$), percent white alone ($p < 0.05$), and rural capacity index ($p < 0.05$) each have a significant positive relationship with the presence of a benefit mechanism.

We adjusted some of the community characteristics included in the model and produced a second model called the **Regional Model**, so

**Table 5**
Results of National Model (n = 1028) and Regional Model (n = 1035).

| Characteristics | National Model | | | Regional Model | | |
|---|---|---|---|---|---|---|
| | B | *se* | *Sig.* | B | *se* | *Sig.* |
| Project | | | | | | |
| Year of operation | 0.053 | 0.012 | 0.000*** | 0.061 | 0.013 | 0.000*** |
| Number of turbines | 0.004 | 0.001 | 0.009** | 0.005 | 0.001 | 0.0006*** |
| Community | | | | | | |
| Market value of agricultural products sold (average per farm) | −0.0000002 | 0.0000002 | 0.348 | | | |
| Population | | | | −0.000001 | 0.0000003 | 0.764 |
| Percent Republican (2020 presidential election) | | | | 0.022 | 0.011 | 0.042* |
| Linguistic isolation rate | 0.021 | 0.014 | 0.145 | | | |
| Median household income | −0.00001 | 0.00001 | 0.249 | −0.00001 | 0.00001 | 0.445 |
| Percent 25 years or older with a bachelor's degree or higher | 0.032 | 0.014 | 0.023* | 0.005 | 0.016 | 0.753 |
| Percent with broadband access | −0.026 | 0.015 | 0.086+ | | | |
| Percent white alone | 0.025 | 0.010 | 0.012* | 0.009 | 0.015 | 0.456 |
| Median value of owner-occupied housing units | | | | 0.000004 | 0.000002 | 0.014* |
| Poverty rate | 0.043 | 0.028 | 0.124 | 0.112 | 0.035 | 0.001** |
| Unemployment rate | −0.124 | 0.072 | 0.088+ | −0.203 | 0.089 | 0.023* |
| Natural amenities scale | −0.064 | 0.039 | 0.0999+ | | | |
| Social vulnerability | | | | −0.005 | 0.005 | 0.322 |
| Rural capacity index | 0.016 | 0.007 | 0.028* | 0.019 | 0.009 | 0.029* |
| Region[a] | | | | | | |
| Far West | | | | −0.577 | 0.451 | 0.201 |
| Rocky Mountains | | | | −0.729 | 0.362 | 0.044* |
| Plains | | | | 0.173 | 0.327 | 0.597 |
| Great Lakes | | | | 0.648 | 0.361 | 0.073+ |
| Southeast | | | | 0.557 | 0.743 | 0.454 |
| Mid East | | | | 1.146 | 0.420 | 0.006** |
| New England | | | | 2.850 | 0.687 | 0.000*** |

*p*-Value: ***$p < 0.001$, **$p < 0.01$, *$p < 0.05$, $+p < 0.1$.
[a] We treated region as a dummy variable, which requires excluding one category of the variable to reduce multicollinearity; Southwest was excluded because it had the highest number of values.

named because it includes a region fixed effect. We were interested in whether including regions might impact the other variables' relationships, given the demographic and socioeconomic differences between regions of the United States. This model (also in Table 5) shows that year of operation ($p < 0.001$), number of turbines ($p < 0.001$), percent Republican voters ($p < 0.05$), median home value ($p < 0.05$), poverty rate ($p < 0.01$), and rural capacity index ($p < 0.05$) each have a significant positive relationship with the presence of a benefit mechanism, whereas unemployment rate ($p < 0.05$) has a significant negative relationship. In terms of the regions, the Mid East ($p < 0.01$) and New England ($p < 0.001$) regions both have significant positive relationships with the presence of a benefit mechanism, and the Rocky Mountains region has a significant negative relationship ($p < 0.05$).

These findings support our first and second hypotheses that projects with benefit mechanisms would be newer and larger than those without. They also support our fourth and fifth hypotheses that host communities with and without benefit mechanisms would differ in terms of percent white and rural capacity index. We were also broadly interested in identifying community characteristics that could explain the existence of a benefit mechanism, and these models reveal several significant variables (e.g., median home value, poverty rate, unemployment rate, percent Republican). It is notable that certain variables found significant in the National Model (e.g., percent white alone, percent 25 years or older with a bachelor's degree or higher) are no longer significant once regional effects are accounted for in the Regional Model.

We calculated odds ratios for each of the variables found to be significant in the National Model (Table 6) and Regional Model (Table 7). The closer an odds ratio is to 1, the less significant the association; however, the units for these variables vary greatly in relative size, and the size of the unit can impact interpretation of the odds ratio. For example, a one-unit increase in project year (in a range of 1982–2024) conveys different meaning than a one-unit increase in median home value (in a range of $48,000–$999,200). All of the odds ratios in Tables 6 and 7 are statistically significant at the 5 % level.

We found it useful to calculate these ratios as percentages for an

**Table 6**
Odds ratios, confidence intervals, and percentages for the National Model.

| Characteristics | Odds ratio | 95 % CI | Percentage (one-unit increase) | Percentage (25th/75th percentiles) |
|---|---|---|---|---|
| Year of operation | 1.055 | 1.030–1.081 | 5.47 % | 61.59 % |
| Number of turbines | 1.004 | 1.001–1.006 | 0.36 % | 23.82 % |
| Percent 25 years or older with a bachelor's degree or higher | 1.032 | 1.004–1.061 | 3.25 % | 21.71 % |
| Percent white alone | 1.025 | 1.006–1.046 | 2.52 % | 60.60 % |
| Rural capacity index | 1.017 | 1.002–1.032 | 1.65 % | 40.74 % |

**Table 7**
Odds ratios, confidence intervals, and percentages for the non-region variables in the Regional Model.

| Characteristics | Odds ratio | 95 % CI | Percentage (one-unit increase) | Percentage (25th/75th percentiles) |
|---|---|---|---|---|
| Year of operation | 1.063 | 1.038–1.090 | 6.33 % | 73.69 % |
| Number of turbines | 1.005 | 1.002–1.008 | 0.50 % | 34.27 % |
| Percent Republican (2020 presidential election) | 1.022 | 1.001–1.044 | 2.20 % | 50.91 % |
| Median value of owner-occupied housing units | 1.000 | 1.000–1.000 | 0.0004 % | 36.28 % |
| Poverty rate | 1.118 | 1.045–1.197 | 11.82 % | 80.82 % |
| Unemployment rate | 0.816 | 0.684–0.970 | −18.37 % | −71.54 % |
| Rural capacity index | 1.019 | 1.002–1.037 | 1.91 % | 48.41 % |

additional perspective. The first percentage column shows that for every unit increase in a given characteristic, there is a certain percentage increase or decrease in the odds of there being a benefit mechanism. For example, for every percentage increase in people 25 years or older with a bachelor's degree or higher, there is a 3.25 % increase in the likelihood that a project would have a benefit mechanism. As shown in Tables 6 and 7, year of operation tends to have a consistently high odds ratio percentage (5.47 % or 6.33 %).

The second percentage column shows a percentage increase or decrease in the odds of there being a benefit mechanism when increasing from the 25th percentile to the 75th percentile of a given characteristic.[5] In other words, it shows percentage change in odds on a larger scale for the predictor variables, making it easier to interpret the effect size in real-world terms. For example, for percent white alone, with an increase from the 25th percentile (73.5 % white alone) to the 75th percentile (92.5 % white alone), there is a 60.6 % increase in the likelihood of there being a benefit mechanism.

As shown in Table 7, for every dollar increase in median home value, there is a 0.0004 % increase in the likelihood of there being a benefit mechanism. When using percentiles, this percentage increases drastically; an increase from 25th percentile ($120,200 median home value) to 75th percentile ($201,775 median home value) corresponds to a 35.57 % increase in the likelihood that there is a benefit mechanism. Interestingly, the *t*-test for home value showed the opposite relationship, with communities with benefit mechanisms having lower median home values.

With the regions, the results are interpreted in comparison to the omitted region category, which was the Southwest, so we have put them in their own table (Table 8) for clarity. For a project in the Rocky Mountains region, there is a 51.8 % decrease in likelihood of there being a benefit mechanism compared to a project in the Southwest. For a project in the Mid East region (similar to the Mid-Atlantic), there is a 214.6 % increase in likelihood, and, notably, for a project in New England, there is a 1628.5 % increase in likelihood.

### 4.5. Model fit

With logistic regression models, Akaike Information Criterion (AIC) scores can be used to evaluate model fit; the caveat is that there is no objective standard against which AIC scores can be measured, as they are only meaningful in comparison to each other. A lower AIC score means better model fit when compared to a similar model. The AIC scores of the National Model (1228) and Regional Model (1204.6) suggest that the National Model is a slightly better fit for the data.

We also used Bayesian Information Criterion (BIC) scores for an additional perspective on model fit; similar to AIC, BIC scores are meaningful in comparison to each other, with a difference greater than 10 considered to be a very strong indicator that the model with the lower BIC is a better fit. The BIC scores of the National Model (1292.2) and Regional Model (1303.4) suggest that the National Model is a better fit for the data.

**Table 8**
Odds ratios, confidence intervals, and percentages for the region variables in the Regional Model.

| Characteristics | Odds ratio | 95 % CI | Percentage |
|---|---|---|---|
| Rocky Mountains | 0.482 | 0.232–0.964 | −51.76 % |
| Mid East | 3.146 | 1.382–7.177 | 214.56 % |
| New England | 17.29 | 4.720–71.475 | 1628.51 % |

[5] Appendix B contains the 25th and 75th percentile values for each variable in Tables 6 and 7.

## 5. Discussion

### 5.1. Wind project characteristics and benefit mechanisms

Based on our assessment of all utility-scale wind projects in the country, we found that nearly one-third of land-based wind projects in the United States have benefit mechanisms associated with them. This suggests many developers have not used use a potentially advantageous tool that has been available to them—one that could provide mutual benefits for host communities and for their goal of expanding the deployment of wind energy. But given our initial perception that benefit mechanisms have rarely been used in the U.S. land-based wind sector, this finding is encouraging; one-third of projects having benefit mechanisms attached to them means that the use of these mechanisms has been less visible or noticed in this sector compared to others, rather than not happening at all.

We sought to understand differences in wind project characteristics between projects with and without benefit mechanisms, and across data analysis methods, project year stands out as a highly significant variable. The fact that newer projects were more likely to have benefit mechanisms was in line with our expectations, as benefit mechanisms have gained increased attention nationally in recent years. In addition to increased interest in distributive fairness [69], growing concern about local opposition to wind projects has likely led developers to consider new methods for gaining support [48,70], including methods they may not have historically considered worthwhile or necessary. One tangible explanation for this trend could be that the COVID-19 pandemic spurred increases in corporate support for community needs; a significant number of benefit mechanisms in our sample were explicitly described as being related to the pandemic. Another factor could be that our data collection method was reliant on the internet and the memories of developers and local officials, meaning it is likely that the benefit data we collected skewed slightly more recent. But given that the mean year of operation for projects with benefit mechanisms was around 2014, we believe this had only a minimal effect.

We also found that larger wind project size (in terms of both generating capacity and number of turbines) is associated with use of benefit mechanisms. The development of larger turbines and projects and the expansion of wind deployment have conveyed a sense that wind energy is getting bigger—and with this, its proximity to and presence in communities is also growing. Along with larger turbines and larger projects, community opposition may also grow [66]. Or, from the distributive fairness and impact compensation perspectives, bigger wind projects would generally be expected to have more benefits to share and more impacts to compensate for than smaller ones. Complexities related to tax and land lease structures could mean that some communities are not seeing the increases in economic benefits they anticipated from larger turbines or larger projects, presenting an opportunity for benefit mechanisms to fill gaps. Given that projects are growing larger over time, our findings related to project size and age may also be linked to each other.

One notable unexpected finding was that the trend drops off after a certain project size, as we find very large projects (in terms of both number of turbines and generating capacity) tended to have lower incidence of benefit mechanism use. Given that larger projects tend to have larger social acceptance hurdles, we found it very surprising that many of the largest projects were sited without the use of benefit mechanisms. A potential explanation could be that these large projects are more likely to be in less-populated areas, hypothetically reducing the need for benefit mechanisms; the host counties for the 30 projects larger than 350 MW had an average population density of 6.95 (in terms of population per square kilometer) compared to 26.84 for all projects. Another factor related to number of turbines could be that some of the oldest projects (located in California) consist of many very small turbines and do not have benefit mechanisms.

In terms of geography, we found that the state and region where a project was located were significant variables associated with the use of benefit mechanisms. One explanation could be that the set of developers operating in each region have different approaches, while another could be regional differences in social acceptance [71]. Only 12.7 % of projects in the Far West region had benefit mechanisms, which might be partially explained by the fact that wind projects in California skew much older than other states. On the other side of the spectrum, more than three-quarters of projects in New England had benefit mechanisms, which is certainly a function of Maine's community benefits requirement [72]. Being in New England gives a project a startling 1629 % increase in the odds of having a benefit mechanism, compared to projects in the Southwest (the region we compared against in the Regional Model).

States and communities with an interest in seeing greater community benefits might consider how state policies have drastically shifted wind development practices in these regions compared to the rest of the country. Other countries provide evidence for this as well; in countries like Germany, Denmark, the U.K., and Ireland, where benefit mechanisms are either required or very strongly encouraged, it is no longer a question of "if" but rather "how" benefit mechanisms will be implemented [20]. In terms of democratizing information, this research could help communities realize how benefit mechanisms have been used in other places, providing tools to help maximize their own benefits from future wind development [73,74].

Many wind projects change hands during their operational lives—sometimes multiple times—making it difficult to use the developer or owner of the project as an explanatory variable in this type of analysis. That said, who the developer/owner is can have considerable influence on what benefits a wind project provides, as each company has its own approach to corporate social responsibility and community engagement. Corporate culture and institutional learning are likely key factors, particularly as developers have gone through trial and error with different benefits approaches. Positioning "developers" as a consistent and one-dimensional group of actors in wind deployment can obscure our understanding of their behavior in this realm. Thus, future analysis using developer as a predictor for the presence of a benefit mechanism could yield useful insights.

### 5.2. Wind host community characteristics and benefit mechanisms

Identifying differences between communities hosting projects with benefit mechanisms and those hosting projects without benefit mechanisms was one of our key motivations in this study, as it is an important aspect of understanding how benefit mechanisms have been implemented and to what end. Though we focused our research questions and hypotheses on economic status, racial demographics, and decision-making capacity, our *t*-tests and regression models allowed us to explore a variety of community characteristics—from education level to political affiliation to agricultural production.

We find a variety of statistically significant differences between communities with and without benefit mechanisms, as well as a variety of characteristics that were predictors of a project having or not having a benefit mechanism. Communities hosting projects with benefit mechanisms had a:

- Higher percent white (and lower percent Black, Hispanic, Asian, and two or more races)
- Lower unemployment rate
- Lower median household income
- Lower median home value
- Lower population density
- Lower population
- Lower market value of agricultural products sold
- Higher energy burden
- Lower linguistic isolation rate
- Lower social vulnerability
- Lower internet access
- Lower natural amenities score.

In our models, the likelihood of a project having a benefit mechanism becomes higher with increases in percent Republican, percent college educated, percent white, poverty rate, rural capacity index, and median home value and becomes lower with an increase in unemployment rate. Some of these trends—both between and within aspects of our data analysis—could be viewed as conflicting with each other or at least not relating to each other and to the benefits/no benefits outcome in the ways we might expect. For example, unemployment rate and poverty rate move in opposite directions, and communities with benefit mechanisms were simultaneously lower in median income and lower in social vulnerability than their counterparts without benefit mechanisms.

Some community variables appeared significant in some analyses but not others. We found through *t*-tests that the two groups differ significantly in terms of median income, population density, population, market value for agricultural products, social vulnerability, internet access, and natural amenities score; however, none of these variables appear significant once included in a model. Percent Republican, percent college educated, rural capacity index, and poverty rate were significant in our models but not in *t*-tests. It should be noted that median home value was the only consistently statistically significant variable for which the trend changed directions between the t-tests and models. A likely explanation for these inconsistencies in the statistical sense is that variables behave differently when in isolation from each other compared to when they are together in a model. A likely explanation in the real-world sense is that inter- and intra-community dynamics and developer behavior are all complicated, and it is a lofty goal to expect clear, consistent trends in this area. These inconsistencies—particularly the lack of a universal trend relating to key indicators like wealth and education—suggest that future research parsing through these relationships would be valuable.

### 5.3. Revealed purposes: considering the purpose for wind energy benefit mechanisms

An overarching interest in this study has been the critical consideration of the purpose for using a benefit mechanism in the development of wind projects, and we were curious about whether our findings could tell us anything—or even just identify new questions—related to purpose. The economic theory of "revealed preferences" posits that actors' preferences can be inferred from the decisions they make [75]; similarly, we were interested in attempting to infer the purpose for developers' use of benefit mechanisms based on their decisions about when and where to use them. The design of this study does not enable us to identify causality, so it should be noted this section is purely speculative.

While we did not assess opposition levels in this study, we can lean on the work of others [3,66] to speculate whether benefit mechanisms might be used primarily to increase local acceptance. We find wind projects with benefit mechanisms are larger and newer and have host communities that are more White, less Hispanic, and more Republican; the same traits have been associated with higher opposition to wind projects in some studies [3,66]. We also find that benefit mechanisms are more likely to exist in communities with higher decision-making capacity, a factor that could give local governments and other stakeholders greater power in both opposing projects and negotiating benefits. This outcome might thus be what one might expect to see if social acceptance was a primary driver of the use of benefit mechanisms. One caveat to note is that developers' conceptions of what makes a community more opposed and more powerful may be based on different characteristics than those actually found to be associated with opposition; decisions about where to distribute benefits might sometimes be based on such predictions made before opposition has fully played out.

Turning to the distributive fairness purpose, we would likely expect to see a shift in the types of communities receiving benefit mechanisms if their primary purpose was to rectify imbalances and address the challenges faced by disadvantaged communities. We find a mixed signal in this area, as there is evidence that both more and less advantaged communities are receiving benefits at a higher rate, depending on which set of variables one uses to define "advantaged." Theoretically, the social acceptance paradigm "could legitimise offering fewer benefits to those communities that readily accept development; yet positive support – and acquiescence – is more widespread in places characterized by disadvantage" [54]. In other words, it might be that some communities have advantages that give them more oppositional power, and developers may respond to that power in ways that reinforce it. Other countries, like Ireland and the U.K., have had challenges in directing the benefits of wind development to more vulnerable communities [20,54]. It should be noted, though, that we are only observing relative differences between communities' characteristics; it may be that some of the relatively more advantaged communities in this study could be considered disadvantaged on the broader national scale.

This is, of course, an entirely theoretical exercise, and a complicated one at that. Given that research in countries like the U.K. and the United States has found the use of benefit mechanisms can actually lower community acceptance [29,31,40,43–45], we could be looking at this relationship in the wrong direction. Communities with certain advantages may also be more adept at maximizing the benefits they receive [8] even without wielding the threat of opposition. On the other hand, communities that are very powerful in their opposition might end up not hosting wind projects at all—a critically important set of communities which is not captured by this study. Understanding benefits offered to would-be host communities for projects that did not succeed would provide additional valuable insights into these relationships. Such post facto analysis as we have conducted in this study cannot provide any certainty about the purpose of using benefit mechanisms, but it reveals a variety of avenues for future inquiry.

The other two purposes we include in our framework, long-term relationship-building and compensation for impacts, were not addressed through our analysis but could provide fruitful directions for future research. Assessing long-term relationship-building as a motivation for developers would require analyzing the timing of when benefits were distributed within the project lifetime—something that is not in the scope of this study but that we plan to explore in future work. With compensation for impacts, focused attention on each wind project might be necessary in order to understand the specific impacts felt by the community and compare these with the benefits offered. Another approach could be to compare the financial value of benefits in relation to recipients' proximity to and/or level of impacts from a project. Within the present study, our finding that communities with benefit mechanisms had a lower natural amenities score might suggest that compensation for visual or landscape impacts, at least, was not a dominant motivation for developers.

### *5.4. Limitations*

The data collection methodology for this study was comprehensive but imperfect, as it relied on historical internet resources and the ability of wind developers and local officials to know or remember benefit mechanism information that may have occurred in the distant past. We found that project websites for many older projects had been taken down, and developers and local officials did not have a consistently high response rate to our inquiries. Though social media posts and news articles provided highly valuable information to fill in gaps, it is likely that we missed some evidence of benefit mechanisms due to a lack of documentation. By studying a large number of projects, we sacrificed the ability to use methods such as interviews that could have helped to collect additional data. We view this research as a first step toward building a foundation of knowledge about benefit mechanisms that spans the entire U.S. wind industry; future research that collects data through other methods and/or focuses on the details of specific cases would be valuable.

Our community characteristics data were taken at the county level, and counties can be quite large in some regions, meaning these data might not perfectly match the community where the wind farm is. However, wind farms are also quite large (often spanning county and even state borders), and benefits were often given on the county level (e.g., donations to a county school district); thus, we determined county-level data were appropriate in this context. Current community data might not always match community characteristics at the time the project was built and/or the time a benefit was given. This could confer some inaccuracies in the case of communities experiencing rapid demographic or economic change, but this is likely only a meaningful consideration for the very old (i.e., 25 or more years old) projects in the sample. Future research could approach this question with a higher degree of temporal and geographic granularity.

Benefit mechanisms in the U.S. wind sector vary widely in terms of structure, monetary value, and other characteristics. Though we focused on the benefit mechanisms' existence or lack thereof in this study, future work might explore how project and community characteristics relate to certain types or attributes of the mechanisms. For example, using monetary value as a dependent variable would allow us to assess whether, within the group of communities that received a benefit mechanism, communities with certain characteristics received more lucrative financial benefits than others. It could be that projects with no benefit mechanism share similarities with those with lower-value benefits, and it is those with higher-value benefits that differ more significantly—a line of inquiry we could not address with this study.

Finally, this study only considers projects that were successfully built and thus does not reflect benefits that were given or promised for projects that were unrealized or are currently in the process of being developed. This research design meant that we could not evaluate the impact of benefit mechanisms on project outcomes, a key question that has been interrogated frequently in other countries but rarely in the U.S. wind energy context. Benefit mechanism information for failed projects would likely be difficult to obtain, given that project websites are taken down after projects are scrapped and given that we found most benefits for (successful) projects were initiated during operations. Still, future longitudinal research identifying causal relationships between benefit mechanisms and project outcomes would be a highly valuable contribution to our understanding of the role and utility of these mechanisms.

## 6. Conclusion

This first-of-its-kind study sought to identify trends in how benefit mechanisms have been used in the U.S. land-based wind sector in relation to the characteristics of the projects and the communities that host them. Motivated by the belief that the purpose for using a benefit mechanism is a critical consideration, we established a framework of purposes relevant to the U.S. wind energy context. We identified differences between projects with benefit mechanisms and those without in terms of project characteristics like size, age, and region and host community characteristics like racial demographics and economic status. We found that it is possible to explain the existence of a benefit mechanism based on community and project characteristics, and we used these findings to make connections to the theoretical purposes for using a benefit mechanism.

Depending on one's perspective, benefit mechanisms are believed to have the potential to increase local support for wind projects, build positive developer-community relationships over the course of a project's life, make wind deployment fairer to communities, and compensate for negative impacts. Despite so much hinging on the use of benefit mechanisms, these relationships are not tested or well-understood in the United States, so it is not clear what impact the mechanisms have had or what purpose has been driving their use. We suggest our finding that communities with certain characteristics in terms of race, political affiliation, and decision-making capacity are more likely to host projects with benefit mechanisms could provide evidence that a primary purpose for the use of benefit mechanisms is increasing social acceptance, given that opposition may be higher (or expected to be higher) in communities with these characteristics. Yet there is also some evidence that the mechanisms have been used to support communities with certain socioeconomic disadvantages, pointing toward distributive fairness as a purpose.

With increasing concerns about local opposition and the growing momentum toward ensuring energy development is fair and even desirable for communities, we expect benefit mechanisms will continue to grow in use and importance across sectors in the United States. Equipped with an industry-scale, national-scale understanding of how benefit mechanisms have been used in the development of wind energy, we are better prepared to explore the utility that benefit mechanisms have—or do not have—for achieving different aims in this area.

## CRediT authorship contribution statement

**Matilda Kreider:** Writing – review & editing, Writing – original draft, Supervision, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Chloe Brush:** Investigation, Formal analysis, Data curation. **Shweta Iyer:** Investigation, Data curation. **Julia Talamo:** Investigation, Data curation. **Alexandra Casey:** Investigation, Data curation. **Chloe Constant:** Writing – review & editing, Supervision, Funding acquisition, Conceptualization. **Suzanne MacDonald:** Writing – review & editing, Supervision, Conceptualization.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Supplementary data

### Appendix A. Wind project data, community characteristics data, and data sources

A list of all wind projects included in this study, project data and community data for each wind project, and data sources can be found online: Supplementary data for "Winds of fortune? Understanding the geographic, sociodemographic, and temporal distribution of benefit mechanisms from land-based wind projects in the United States" (Figshare).

### Appendix B. Supplementary data for national and regional models

The 25th and 75th percentile values for each variable found to be significant in the national and regional models can be found online: Supplementary data for "Winds of fortune? Understanding the geographic, sociodemographic, and temporal distribution of benefit mechanisms from land-based wind projects in the United States" (Figshare).

## Data availability

The data that has been used in this study is available online, as referenced in Appendix A.

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